

**IN THE SPECIFICATION**

Please amend paragraph [0034], which is the first full paragraph on page 7 of the published PCT application, as follows:

Referring to Figure 2, first stage focussing means 24 are shown comprising a first micro-scale lens system. This micro-scale lens system is disposed to collect and focus the particle beam from the accelerator **aperture 20.** ~~aperture 22.~~ Figure 2 shows the focussing effect on the beam profile 26. This lens is an aberration corrected cylindrical einzel lens consisting of three cylindrical elements 28, 30 and 32. The outer two elements 28 and 32 are at earth potential and the central element is supplied with a voltage sufficient to focus the electrons at the required position. (Either polarity voltage can be applied but the aberrations are the smallest for a positive voltage, when used to focus electrons, and a negative voltage when used to focus positively charged ions.) An approximate scale of this particular micro-lens is shown at the top of the figure. As an example, in the diagram the beam is focused at a sample holder 34a which can be moved laterally to scan the sample and along the beam axis to adjust the focus. The aberrations in this lens are corrected by adjusting the relative dimensions marked **a, b, l and t** ~~x, y, l and t~~ on the sections of Figures 1 and 2.

Please amend paragraph [0052], which is the paragraph bridging pages 10 and 11 of the published PCT application, as follows:

Figure 4 shows the geometry of a four-element lens with electrodes labelled 48, 50, 52 and 54 with voltages V1, V2, V3 and V4 respectively. The beam and **its** ~~[[it]]~~ direction are labelled 56. A first analysis position, 58, is a focus distance, f1, from the end of the microscale lens. Scanning of the beam is achieved by moving the sample using piezos as is usual in scanning tunnelling microscopy. This sample position can be removed and the beam made to travel through the second miniature lens so as to come to a focus at a distance, f2, from the end of the second lens. At this point there is a piezo driven sample holder, 60. Although this second miniature lens is shown as having the same geometry as the first lens this need not necessarily be the case. Again the exact

geometry (aperture sizes etc) will depend on the beam properties as it passes through this lens. Typical aperture sizes are around 5 $\mu$ m for the microscale lens and 5mm for the miniature lens but these can be varied over a wide range.

Please amend paragraph [0053], which is the only full paragraph on Page 11 of the published PCT application, as follows:

A further embodiment of the present invention is shown in Figure 5, wherein a particle beam generator is a micro-chip 100 comprising one or more nanocolumns 162 which produce a narrow (<50 nm) on-axis beam. A nanotip 114 is at the end of a microstructure which is attached to the vertical cantilever (not shown) and positioned centrally and greater than 10nm from the first aperture 113 ~~[[13]]~~ of the nanocolumn 162. The nanocolumn 162 can be in one or more parts as shown and defines an axial beam of lateral dimensions less than 50nm. A typical nanocolumn 162 ~~nanocolumn162~~ is shown in figure 5b and is made of a thin multi-layer film consisting of alternate metal (conducting) layers, 118, interspaced with insulating layers 119 through which a circular aperture 113 ~~[[13]]~~ is made by lithography or using a focussed ion beam (FIB) 'milling machine'. The total length of the nanocolumn(s) may be up to 2 $\mu$ m and is sufficient to accurately determine the (on-axis) direction and phase space emittance of the beam. The nanotip 114 is positioned above the aperture as shown and a voltage differential is applied between the tip 114 and the nanocolumn electrodes 162. The beam defined by the nanocolumn has an axis 164 which is concentric with the multi-element, microscale, einzel lens. This lens consists of metal (conducting) electrodes 166 interspaced with insulators 168. The assembly shown consists of four metal electrodes interspaced with insulators and is positioned at distances of only a few microns from the nanocolumn from which it is separated by an insulating film with an aperture of the same dimension as the microlens. Suitable aperture diameters for this lens are given in the previous application. Increasing the number of metal conducting electrodes in the stack can reduce aberrations in this lens.

Please amend paragraph [0054], which is the only full paragraph on Page 12 of the published PCT application, as follows:

Figure 6 shows one of the ways of constructing the microscope so that it is possible for the microlens to focus the beam at a point less than 50 $\mu$ m from the end of the instrument. This condition is necessary if the beam is to have a lateral size less than 1nm and approaching 1Å. (This beam spot essentially determines the resolution of the instrument.) An application of this embodiment of the present invention is shown in near field microscopy in Figure 6b and consists of the 'chip' or body 100 rigidly attached to a horizontal cantilever arm 170, of a near field microscope, which can be positioned using standard techniques of nanopositioning. A vertical cantilever above this holds the nanotip 114 and this can be moved vertically and scanned in the horizontal plane. The sample is mounted on a special retainer 172 which has a small surface area for attaching the sample. (This atomic resolution arrangement can only accommodate small area sample; for larger areas the focal length of the microlens is increased and the resolution degrade to around 1nm.) A further vertical cantilever 174 ~~cantilever174~~ below the microscope body holds the sample retainer and provides a means of positioning the sample at the correct vertical distance as well as scanning in the horizontal plane.

Please amend paragraph [0061], which is the paragraph bridging pages 14 and 15 of the published PCT application, as follows:

A further embodiment of the present invention is shown in Figures 7 and 8, wherein a particle beam generator 200 comprises a pair of thin film metallic layers, 212 and 213 separated by a semiconductor material 284. Each of the metallic layers comprises collimating apertures 286 and 288 (nanocollimators). The beam generator 200 also comprises an accelerating aperture 220 which extends through the semiconductor material and shares a longitudinal axis with the collimating apertures 286 and 288. The diameter of the accelerating aperture 220 is greater than the diameter of each of the collimating apertures 286 and 288. Typically, the diameter of the accelerating aperture might be around 50nm and the nanocollimator apertures of about 30 nm. Particles will be emitted from the nanotip 214 if a sufficient voltage difference exists between the tip and the collimating aperture 286. These particles will be accelerated and focused into an almost parallel beam if the voltage difference across the semiconductor is sufficiently large enough. (The arrow 290 shows the electron beam direction in both Figures 7a and

7b). Typically for an  $0.5\mu\text{m}$  silicon thin waver, or film, the voltage across the semiconductor might be around 300 volts and this will generate a uniform field along the hole of  $600\text{MV/m}$ . A longer nanocolumn is possible if it is made in two stages as shown in Figure 7b. Here there are two layers separated by a conducting film 213. The bottom layer ~~215~~ 285 is conducting and can be made from metal or preferably very low resistivity doped silicon. If the two metal films 213 and ~~215~~ 244, are at earth potential then the whole bottom column 285 is at earth potential. The nanoaperture 286 performs the same function as in the device shown in Figure 7a but the aperture 288 which can be several microns from the nanotip is able to reduce scattering whilst further lowering the (phase space) emittance of the electron beam. The hole in this lower column 285 is fabricated at the same time as that of the upper accelerating section. Its sole function is to support the nanoaperture 288 concentric with the hole in the semiconductor. A narrow electron beam, which is limited in diameter to the aperture size 288 then passes to the electrostatic focussing elements of the microscope as shown in Figure 8.

Please amend paragraph [0062], which is the paragraph bridging pages 15 and 16 of the published PCT application, as follows:

A complete particle beam generator system for use as a microscope is shown in Figure 8 with the accelerating aperture 220 ~~hole in the nanocolumn 290~~ and the nanotip 214 being the source of electrons. The narrow beam of electrons 222 passes from the nanocolumn 286/288 and through a concentric einzel lens as shown. This lens is a simple three-element arrangement which is manufactured from conducting and insulating layers, 292 and 294, respectfully through which an aperture is manufactured. Multiple element lenses, containing five or more electrodes, are also possible to reduce aberrations as previously mentioned for other embodiments. The inside diameter (aperture of the lens) and spacing of the electrodes is chosen to give minimum aberrations and hence the smallest beam spot. Typical dimensions for the lens are about  $2\mu\text{m}$  for the inside diameter and each layer being about  $1\mu\text{m}$  thick. Manufacture of the einzel lens is simplified if it is made from a single thin waver of three distinct layers. Using silicon at different doping concentrations can produce a conducting layer 292 and an insulating layer 294. For a simple 3 element lens the outer two conducting electrodes are at earth

potential and the central one is at the correct voltage to give a focus at the desired distance from the end of the assembly 296. This whole assembly forms the body of the microscope and when this is fabricated at the edge of a stepped assembly as previously mentioned in another embodiment the beam generator is essentially a single chip apart from the nanotip. However this nanotip is at the end of a cantilever so that it can be positioned on the centre of the nanocolumn entrance aperture and can thus be integrated into the nanochip to make a complete focussed electron (ion) beam machine, namely a 'Microscope on a Chip'. Note that the resistive film from which the microscope body is made can have many holes in it so that they can all be accessed by moving the nanoprobe to any entrance aperture.

Please amend paragraph [0063], which is the paragraph bridging pages 16 and 17 of the published PCT application, as follows:

In the previous embodiment an accelerating nanocolumn is constructed from a multilayer structure of alternate metal (conducting) and insulating layers through which is a hole of diameter of less than 100 nm is fabricated and is the channel down which the electrons pass. By applying voltages to the conducting electrodes in this assembly it is possible to produce a high electric field along the evacuated aperture in the column. This embodiment is a simpler method of producing nanocolumns or accelerators which have the same effect as the previous assembly. Furthermore this new device is simpler to manufacture and can accommodate the inclusion of restricting (anti-scatter) collimators at both ends of the column. The method is to manufacture the accelerator from a single sheet of high resistivity material through which holes are produced using microfabrication techniques. The favoured material, though not the only possibility is single crystal doped silicon as used for the manufacture of microchips. The doping will normally be n-type (though p-type is possible) and the doping density should be such that the resistivity is in the range from 1 k $\Omega$ m-cm to 100 M $\Omega$ m-cm but not exclusively. A voltage applied across a thin film of such a material will ensure that there is a uniform electric field along any straight hole through the resistive material. The hole is made normal to the parallel sides of the thin wafer or film, which is the body of the accelerator and can be loosely termed a nanocolumn, in line with the previous terminology for a

column constructed from a multilayer of alternate insulating and conducting thin films. (Nanocolumn is used ~~because the~~ because the aperture through the film is in the nanometre size range.) In this circumstance the electric field is along the (evacuated) hole and it can thus accelerates electrons injected into the hole. A nanotip, which can be positioned above a hole of typical aperture 50 nm and at a distance of around 30nm, will field emit electrons if the voltage on the tip exceeds that of the surface by about 10 volts. Both surfaces of the semiconductor are covered with a thin metallic film through which holes are manufactured concentric with the hole in the semiconductor. The diameter of the holes in the metallic film are smaller than that in the semiconductor so that these apertures act as anti-scatter collimators and can also be used to reduce the electron beam emittance.

Please amend paragraph [0066], which is the only paragraph on Page 18 of the published PCT application, as follows:

General arrangements are shown in Fig. 9, with the electron source being a nanotip 314 at the entrance to the first nanoscale section of the device with the beam direction 390 being marked. Figure 9a shows a section of material 301 of micron thickness through which is fabricated a 50nm (typical size) circular hole by dry etching techniques. The walls of this hole can be made parallel if the etching is carefully controlled. The whole microscope column or assembly can be made with accelerating sections and non-accelerating sections as described in a previous embodiment. One method of fabricating these apertures 386 and 388 ~~286 and 288~~ is as follows. During the production of the hole, registration features 398 are produced on the surface to delineate the aperture position. The surface is then coated with a nanometer thick gold layer by vacuum deposition techniques (atomic deposition from a source) and a 2-3nm (typical) thick gold foil, 312 and 313 is placed over the aperture on top of this first layer. (If this is done in clean conditions the gold foil will bond to the vacuum deposited gold layer on the silicon.) It is then possible to produce apertures, 386 and 288 ~~286 and 288~~ in this metal foil by ion beam drilling or dry etching. (For this to be possible it is important that the registration remains visible after the gold layer is applied.) Figure 9b shows an alternative way of producing an aperture particularly at the entrance to the accelerating

section. In this method the hole is tapered into a conical shape as shown. This tapering can be produced by carefully controlling the dry etching process. The top conducting layer 399 is then made by depositing a metal on the surface using standard vacuum deposition methods. A further aperture made by the previous method can be placed below this assembly as shown in the central diagram. However it is also possible to produce a collimator at this position by placing a second wafer with a tapered hole in it below the one shown in the central diagram. This then replaces the aperture made from thin film metal (gold). It can be made in a separate thin wafer (of silicon) which is positioned so that the holes are concentric or the whole assembly can be fabricated in one piece. Thus the system now consists effectively of two wafers with conical holes with both wafers vacuum coated on their flat sides with metallic films. It is also possible to produce a collimator from the intrinsic material of the wafer not necessarily in the form of a taper as is shown in Figure 9c. Collimators can be manufactured at either or both ends of the assembly or assemblies (wafers). These can be stacked to minimise scattering and/or reduce the phase space emittance of the beam.